Potential and environmental concerns of ethanol production from sugarcane molasses in Pakistan

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Introduction:

Interest in alternative transportation fuels is growing for two main reasons: oil supply insecurity and its impending peak, and the imperative to lower greenhouse gas emissions from fossil fuel use in order to stave off adverse global climatic changes[1,2]. Renewable energies are essential contributors to the energy supply portfolio as they contribute to world energy supply security, reducing dependency of fossil fuel resources, and providing opportunities for reducing emissions of greenhouse gases[3]. Energy security and climate change imperatives require large-scale substitution of petroleum-based fuels as well as improved vehicle efficiency[4]. Biofuels have become one of the fastest growing markets in the world – at 15% growth a year. With oil prices steady above $90 a barrel biofuels have become competitive. Whilst it attracts subsidies in Europe, United States and Brazil have shown that a mature biofuel industry can now compete with petrol on the free market. Although biofuels offer a diverse range of promising alternatives, ethanol constitutes 99% of all biofuels wherever the blends are made mandatory in the world.

Economic development in the third world has historically taken precedence over environmental concerns. The two, however, are not unrelated. Studies suggest that the costs associated with pollution in Pakistan may be as high as 5 % of the gross domestic product (GDP). Our cities are particularly susceptible to the health hazards of environmental degradation. Urban air pollution in Pakistan is estimated to be 20 times higher than the World Health Organization’s minimum standards. The largest contributors to air pollution are vehicular emissions of greenhouse gases, sulfur oxides, and particulate matter.

In the light of this situation, the government’s efforts to promote the use of compressed natural gas (CNG) as an alternative fuel are impressive. Compressed natural gas has many advantages over petrol. First, it is quieter, smoke-free, and significantly reduces harmful emissions. Second, it is cheap, given our large natural gas reserves. This is a significant achievement, however, at current levels of demand, proven natural gas reserves will only last another 30 years. It is imperative to work out and implement a strategy towards having a renewable energy source that can replace CNG, petrol, and diesel in the near future.

Efforts to substitute alternative fuels for petroleum are gaining attention in a world threatened by climate change, rural economic decline, and instability in major oil-producing countries. Biofuel crops take in carbon dioxide from the atmosphere while they are growing, offsetting the greenhouse gases released when the fuel is subsequently burned. Replacing petroleum with bio-fuel can reduce air pollution, including emissions of fine particulates and carbon monoxide. Bio-fuel production also can improve rural economies by creating new jobs and raising farm incomes. As a locally produced, renewable fuel, ethanol has the potential to diversify energy portfolios, lower dependence on foreign oil, and improve trade balances in oil-importing nations.

Renewable energies are essential contributors to the energy supply portfolio as they contribute to world energy supply security, reducing dependency of fossil fuel resources, and providing opportunities for reducing emissions of greenhouse gases. According to the World Bank, the only potential renewable fuel anywhere in the world that can currently compete with petrol is ethanol from sugarcane. Pakistan produces the world's 5th largest sugarcane crop, of which 20 percent is exported[5]. Scenarios developed for the United States and the European Union indicate that near-term targets of up to 6% displacement of petroleum fuels with biofuels appear feasible using conventional biofuels, given available cropland. A 5% displacement of gasoline in the EU requires about 5% of available cropland to produce ethanol; while in the US 8% is required. The potential global production of biofuels for transport is not yet well quantified. However, based on some conservative estimates, it appears that a third or more of road transportation fuels worldwide could be displaced by biofuels (Ethanol and Biodiesel) in the 2050- 2100 time frame[6].

In fact, until recently, Pakistan was the second largest exporter of sugarcane ethanol to the European Union — a preferential status we have since lost because of WTO obligations and dumping complaints. Several distilleries have planned to close down in light of this fact. Instead of curbing production of fuel ethanol, however, we should redirect it to the domestic market. Eventually, a domestic industry will grow, and the further development of sugarcane feed stocks will accelerate rural infrastructure development and result in rural job creation from farms and processing facilities.

The most significant progress towards ethanol use as an alternate fuel is made by Brazil. Global annual ethanol production from biomass is estimated at 18 billion liters, 80% of which is in Brazil[7]. Ethanol as fuel represents 20% of Brazil's primary energy supply, aided by significant increases in the past 20 years in the use of ethanol fuels for vehicles[8]. Experiences with fuel ethanol in Brazil and around the World suggest that government action is essential in the initiation of such programs to coax the market away from pre-existing technologies. A Pakistani fuel ethanol program, like its CNG predecessor, will need initial government support to develop an infrastructure in which the new industry can grow.

Ethanol as Fuel:

Substitution of Petroleum by ethanol as a motor fuel has already gained universal recognition. Several countries of the world have successfully developed their fuel Ethanol program. Total world ethanol production is about 40 billion liters. Global fuel ethanol production doubled between 1990 and 2003, and may double again by 2010[3]. Brazil is leading with an annual production capacity of 12-15 billion liters and a share of 36% in world s production. Brazil is followed by USA (8-10 billion liters) with a share of 26%, China (3.6 billion liters) with a share of 9.5%, European Union (2.5 billion liters) having a share of 6.5%[9]. Brazil's sugarcane and sugar continues playing a leading role in the World. It is expecting a jump of 35% in the sugarcane production in the next five years from 420 million tons to 586 million tons. The ethanol production is also expected to move along from 16.7 billion litters to 26.5 billion litters for which 50 new ethanol and sugar refineries are under construction. In India, the government has made mandatory 5

% blending and the distilleries there are producing 1.3 billion liters ethanol out of 2.82 billion liters installed capacity[10].

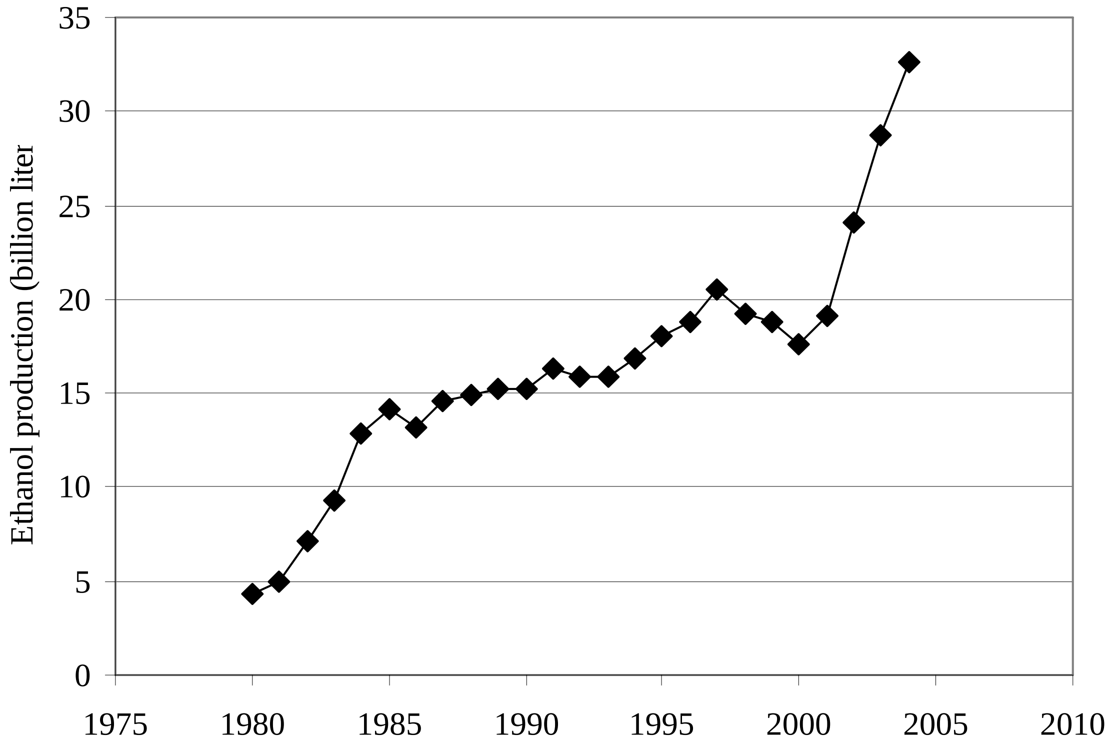

Figure 1. World ethanol production from 1980-2004 (Worldwatch/International Energy Agency, 2005).

The ethanol fuel is a renewable fuel and it does not deplete the resources as in the case of petrol. Since alcohol has an octane number of 99 while petrol has 90, therefore, if petrol is blended with 10 per cent ethanol, its octane number can also increase to 91. Higher octane number of alcohol gives the higher compression ratio and higher thermal efficiency, improving engine performance.

Feedstock for Ethanol Production:

Major feed stock for ethanol production can be divided into three major groups: 1) Beet, sugar cane, sweet sorghum and fruits; 2) Starchy materials such as corn, milo, wheat, rice, potatoes, cassava, sweet potatoes, etc., and 3) Cellulosic materials like wood, used paper, crop residues, etc. Sugarcane molasses are considered as the cheapest source of ethanol production however use of cane juice (especially secondary juice) directly for the fermentation and production of ethanol seems to be the most economical and value-added concept for sugar factories.

It has been estimated that around 80 percent of the world's molasses is used for alcohol production. Molasses is converted into ethanol (ethyl alcohol) through biochemical processes based on fermentation. Alcohol as fuel blends is economically successful in countries where oil is more expensive or where independence in fuel supply is seemed as a political or strategic problem. In Brazil, the program to promote ethanol production was established in 1970 to reduce the country's dependence on imported oil, and to help stabilize sugar production. Now most of cars and light vehicles use either neat-ethanol (94 % ethanol, 6% cent water) or gasohol (78 % gasoline, 22 % ethanol) as fuel. Brazil has demonstrated technological developments, in both agriculture and cane processing, leading to lower ethanol costs and the possibility of a large surplus in biomass-based (bagasse and trash) electricity[10].

Due to simplest conversion process sugar bearing materials are technically amongst the most attractive biomass material. In Pakistan under present conditions, molasses is the most promising raw material for the production of fuel alcohol. Molasses is the by-product of sugar industry and major portion of that is exported[9]. Increasing the use of ethanol as bio-fuel can improve energy security, reduce greenhouse gas and pollutant emissions, improve vehicle performance, enhance rural economic development and, under the right circumstances, protect ecosystems and soils. However, these benefits are difficult to quantify, the market price of biofuels does not adequately reflect them[6]. In most countries embarking on bio-fuels initiatives, the recognition of non-market benefits is often the driving force behind efforts to increase their use. These benefits are: 1) Reductions in oil demand, 2) Reductions in greenhouse gas emissions, 3) Air quality benefits and waste reduction, 4) Vehicle performance benefits, and 5) Agricultural benefits etc.

Prospects of Ethanol as Fuel for Pakistan:

Pakistan has for the first time announced the promotion of blended gasoline with ethanol in the transport sector. The blended fuel will have up to 10 % ethanol and remaining gasoline. Ethanol is considered to be the cheapest and environment friendly fuel as it costs only US$ 0.32 per liter against the price of US$ 0.97 per liter of gasoline (Gasoline price in Pakistan). Test runs of vehicles are underway in the major cities. Pakistan State Oil (PSO) is spearheading the initiative for implementing the Government of Pakistan Policy on sustainable basis.

Pakistan produces around 2 million tons molasses annually, out of which 1.45 million tons were exported at a nominal rate of $35 per ton, earning only $47 million in 2004. Ethanol recovery from one ton of molasses is estimated at 240 to 270 liters depending on the quality of molasses. If the entire two million tons of molasses are processed in distilleries, ethanol production will be over 500 million liters (0.4 million tones), and on exporting the same at an average price of $360 per ton, the country can earn around $144 million. Thus, there is a glaring difference in earning foreign exchange between two products. At present, national output is around 0.123 million tons ethanol that fetches around $44.35 million through exports[10].

The commercial utilization of molasses in the Pakistan is very limited, major portion of the commodity is exported. Presently, 13 distilleries are operating in Pakistan. Of these 10 are attached with sugar mills, out of which eight are operational and two are non operational. Production capacity of 10 distilleries attached with sugar mills is about 143 million liters of ethyl alcohol per annum, which is equivalent to consumption of approximately 0.560 million tones of molasses. In addition, three distilleries not attached with sugar mills are producing 6.5 million liters per annum alcohol and also three existing distilleries attached with Habib, Al-Abbas and Shakarganj sugar mills are increasing their capacities. It will expand existing capacity by additional about 105 million liters per annum, augmenting the aggregate capacity with likely production roll out on efficient performance level to 314.5 million liters. It is expected that number of distilleries will increased to 21 with capacity of 504 million liters by 2005-06[9]. Total installed alcohol production capacity is 500 million liters out of which only 2.5 million liters is locally consumed and rest (397 million liters) are exported. Alcohol export increased from 6 million liters in 1994-95 to 37 million liters in 2003-04. However, Pakistan, the second largest ethanol exporter to the EU, has lost its privileged status since 2005. Although Pakistan still benefits from a 15 percent reduction in the import duty, Pakistani ethanol does not appear to be competitive in the European market. Loss of trade with EU has led to the closing of two of the seven operating distilleries, and that another five new distilleries will probably abandon plans to begin operations due to uncertainties of the market situation[11]. The quantity of ethanol exported to EU can be converted in the form of industrial, superfine or fuel ethanol. However, its conversion into fuel ethanol is dependent on the government's indigenous fuel ethanol program.

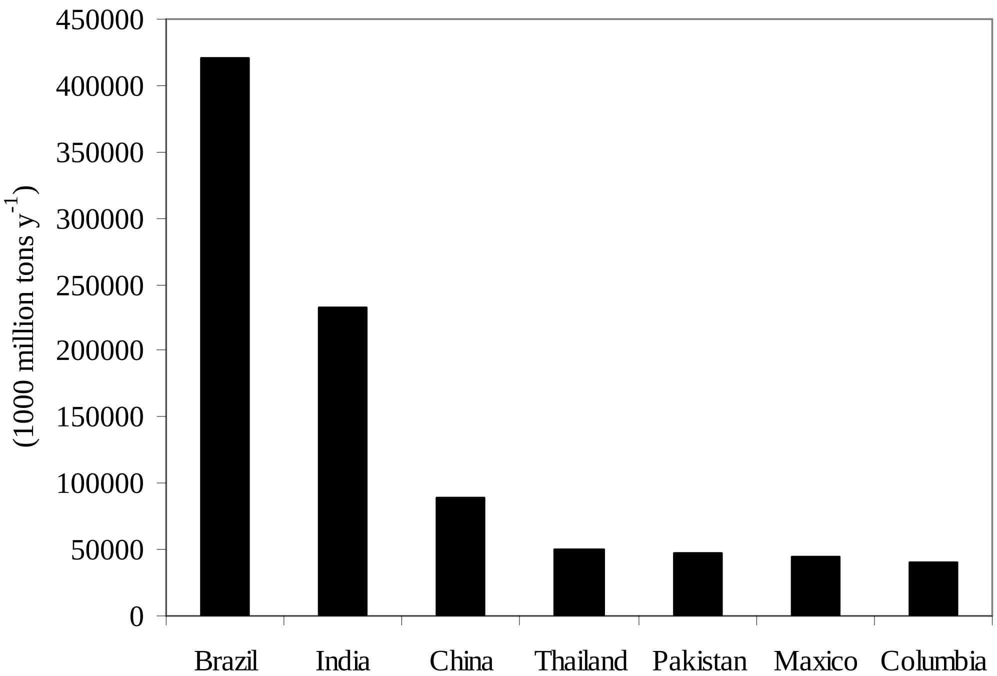

Figure 2. Sugarcane production of major sugarcane producing countries. (Source: FAO, 2005[29])

Presently Pakistan imports petroleum products to the tune of 3.1 billion US $, which has made a significant contribution to the rising trade deficit of the country. In order to address this issue, it is high time to explore other options for fuel requirement of the country. Pakistan's expected consumption of petrol in the year 2005-06 would be around 2 billion liters, if the country starts blending ethanol with the ratio of 10%; we need 199.85 million liters of ethanol as fuel, which is only 40% of our installed ethanol production capacity. If we can use a blend of 80:20 in our vehicles, the required quantity of ethanol will be 80% of the installed capacity. These calculations show that we can start blending of ethanol with petrol without any delay with a minimal investment. At 10%

blending ratio Pakistan can save US$ 63.5 million, which is about 2% of our fossil fuel oil import bill. Ethanol use as fuel in Brazil is about 20% of the total fuel consumed for transport. Ethanol-only cars were sold in Brazil in significant numbers between 1980 and 1995; between 1983 and 1988, they accounted for over 90% of the sales. Eighty percent of the cars produced in Brazil in 2005 were dual-fuel, compared to only 17% in 2004[12]. However, if we include the environmental pollution due to green house gas (GHG) emissions by fossil fuel combustion the scenario will totally change as use of ethanol as fuel in terms of GHG emissions.

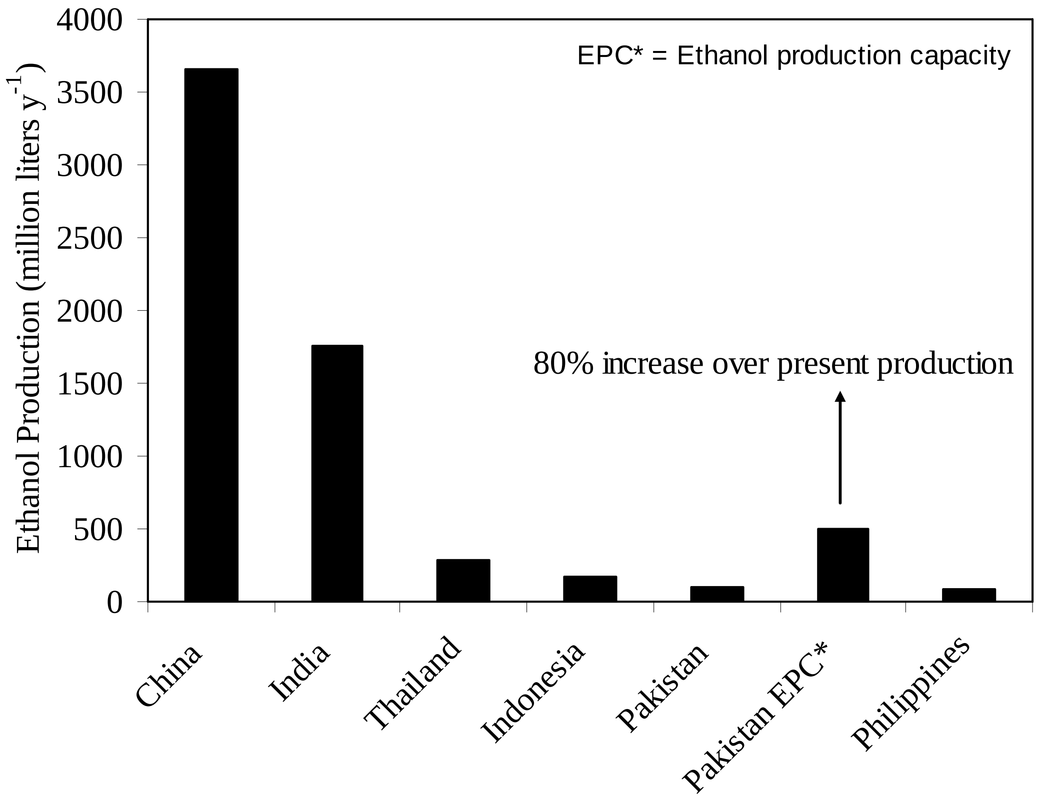

Figure 3. Ethanol production in Asian countries and potential ethanol production in Pakistan. (Sources: RFA, 2005 and PSMA, 2005)

Potential Reduction in Green House Gas Emissions:

Atmospheric concentrations of greenhouse gas (GHGs) have been increasing as a result of wide range of human activities and have been particularly noticeable after 1950s. This increase is believed to alter the redistribution of energy in the atmosphere and consequently, affect climate by altering some related natural phenomenon, such as the mean global, temperature change in frequency and distribution of precipitation, circulation and weather patterns and hydrological cycle, among others[13]. The anthropogenic emission of GHGs has been considered as a major concern within the scientific community as well as the general public in the last few years. Such a concern was the basis for the creation of the Intergovernmental Panel on Climate Change (IPCC) and for the process of international negotiation that led to the approval of the United Nation Framework on Climate Change (UNFCC). The government of Pakistan also signed the convention that was ratified on 1995.

Molasses ethanol has a closed cycle, where energy for the refinery and distillery process comes from sugarcane residues (bagasse and other waste) hence no fossil fuel are needed. For every energy unit invested, molasses ethanol yields 8.3 units in Brazil followed by sugar beet, which yields 1.9 energy units for every unit put in France[14]. Corn ethanol as energy source is still controversial due to energy input and energy out put ratio and under debate[15]. One study found that a hectare of land in Brazil grows enough sugar cane to make ethanol, which saves 13 tons of CO_2 every year, by replacing petrol or diesel. If, however, natural forests were allowed to regenerate on the same hectare of land, the trees would absorb 20 tons of CO_2 every year[16]. There is no conclusive study life-cycle assessment that takes all emissions from different types of land-use change and from soil erosion and fertilizer use into account.

Total green house gas emissions in Pakistan were 137. 12 MMT CO_2eq in 2000 out of which 20% emissions (27.5 MMTC) were due to transport sector[17]. Energy related CO_2 emissions are 104.4 MMT, of which crude oil and natural gas contribute 46 and 45% respectively[18]. Pakistan's expected consumption of petrol in the year 2005-06 would be around 2 billion liters. If the country starts blending ethanol with the ratio of 10% and as a result the ethanol requirement would be 200 million liters. Use of ethanol as fuel will reduce GHG in the order of 20% to 50% compared with petroleum fuels[19]. However, these figures are controversial and a more conservative estimate of 13% less GHG emissions due to ethanol use, as a fuel looks more realistic[15]. By considering 13% savings in GHG emissions due to the use of ethanol as fuel Pakistan can reduce its energy sector GHG emissions from 104.4 MMTC to 90.8 MMTC per year. This reduction in GHG emissions from energy sector will play a significant role to meet GHG reduction targets set under Kyoto protocol.

Environmental and Health Concerns:

The energy and environmental implications of ethanol production are more important than ever. Much of the analysis and public debate about ethanol has focused on the sign of the net energy of ethanol: whether manufacturing ethanol takes more nonrenewable energy than the resulting fuel provides[20]. It has long been recognized that calculations of net energy are highly sensitive to assumptions about both system boundaries and key parameter values[21]. In addition, net energy calculations ignore vast differences between different types of fossil energy[22]. Moreover, net energy ratios are extremely sensitive to specification and assumptions and can produce un-interpretable values in some important cases[15]. However, comparing across published studies to evaluate how these assumptions affect outcomes is difficult owing to the use of different units and system boundaries across studies. Finding intuitive and meaningful replacements for net energy as a performance metric would be an advance in our ability to evaluate and set energy policy in this important arena.

Evaluations of biofuel policy should use realistic assumptions (e.g., the inclusion of co-product credits calculated by a displacement method), accurate data, clearly defined future scenarios, and performance metrics relevant to policy goals like reducing greenhouse gas emissions, petroleum inputs, soil erosion and cost of land conversion cost. Progress toward attaining these goals will require new technologies, practices as well as the transparent enthusiastic implementation from top to bottom. Such an approach could lead to a biofuels industry that, in conjunction with greater vehicle efficiency, could play a key role in meeting the nation’s energy and environmental goals.

Although nearly all governments believe that biofuels should be classed as ‘renewable energy’, however, only sustainably sourced biofuels should be certified as renewable energy. It is essential that mandatory certification is put in place before any further expansion of the biofuel market, or any further large-scale land conversions are pursued. Ideally, this would be part of an international agreement, but meantime individual countries and purchasers to reduce the market for destructive biofuels and create a sustainable renewable energy sector must adopt it[23].

The best examples of damaging side effect of sugar-cane cultivation can be quoted from Brazilian Ethanol Industry. There is abundant scientific evidence of environmental degradation from soil erosion in sugar-cane fields is widespread[24]. In the state of Sao Paulo, which is the core of the ethanol industry in Brazil, estimated rates of soil erosion in sugar-cane fields are up to 30 Mg of soil per hectare per year[25]. Smoke pollution from sugarcane fields will continue to be a major problem in Sao Paulo and other Brazilian states for many years, leading to further acidification of the already poor tropical soils[26]. Additionally, high particulate concentrations in the atmosphere from sugarcane burning have been associated with a growing number of human respiratory diseases in sugar-cane regions[27, 28].

We believe that the ethanol industry and proposals for expansion of ethanol production in Pakistan and else where should be carefully evaluated, to avoid environmental and social problems far outweighing long-term economic gains. It is therefore necessary to formulate a comprehensive strategy for the promotion of molasses ethanol as fuel in the country in the light of following considerations:

1. Energy and greenhouse gas balance of molasses ethanol, including the best evidence on CO_2 and N_2O emissions;
2. All impacts of sugarcane production on soils, atmospheric pollution and water supplies;
3. The impact on local sugar supplies for human consumption (a very crucial factor in Pakistan);
4. Social and economic impacts on local populations (another very important issue in Pakistan as mill owners don't pay farmers on time and even not the full amount);
5. Funding should not be provided without complete scientific assessment of the whole process of ethanol production i.e. "Cane to Van" analysis;
6. It is hygroscopic. Therefore, its storage must be in spaces such that water contamination can be completely avoided;
7. It is highly volatile. Therefore, its blending, transportation and engine start up problem need investigation and research. The volatility of fuel Ethanol considered to be contributing factor for the formation of ozone at the ground level (summer smog);
8. The engines using high level of Ethanol in gasoline are likely to omit carcinogenic aldehides;

9. There is a possibility of sulfate contamination at the fuel stations posing serious health problems to the workers;

10. The older cars shall be at greater risk of getting damaged sooner due to the solvent nature of the Ethanol, in respect of the material use for their gaskets and seals;

11. Regulatory framework for the production and marketing of fuel ethanol;

12. Social Acceptance of the blended fuel (gasoline with fuel ethanol) etc.

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